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Effect of dietary high-oleic acid and conventional sunflower seeds and their refined oils on fatty acid composition of adipose tissue and meat in broiler chickens*

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ABSTRACT

The influence of different dietary fat source on performance, tissue fatty acid composition (abdominal fat, thigh and breast muscles) and abdominal fat melting point was evaluated in female broiler chickens. Birds were fed diets containing 80 g/kg of added fat by the inclusion of high-oleic acid sunflower seed (HOASS) and conventional sunflower seed (CSS), their respective refined oils (HOASO and CSO) and lard during three weeks (from 21 to 42 d of age). Feed efficiency was significantly impaired by the inclusion of HOASS and CSS in diet when compared with HOASO, CSO and lard. The levels of the major fatty acids (palmitic, oleic and linoleic) in each animal tissue reflected the fatty acid profile of the dietary fat (r^2 >0.83). The linear regression analysis between fatty acid content and melting point of abdominal fat gave the highest coefficient of determination for the saturated fatty acid content (r^2=0.80). It is concluded that the seeds of high-oleic acid and conventional varieties of sunflower might be used in poultry feeding in order to increase, respectively, monounsaturated and polyunsaturated fatty acid contents in both abdominal adipose tissue and intramuscular fat. The feeding of both types of seeds had similar effects to their respective refined oils on the unsaturated to saturated fatty acid ratio of the chicken tissues and on the melting point of abdominal fat. Nevertheless, they showed a negative influence on fat firmness when compared with the dietary inclusion of lard.

KEY WORDS: broiler, high-oleic acid sunflower seed, sunflower seed, meat, adipose tissue, fatty acids

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INTRODUCTION

The nutritional benefits of unsaturated fatty acids (UFA) in human diets are well known. Numerous studies have shown that the substitution of dietary SFA for monounsaturated (MUFA) or polyunsaturated fatty acids (PUFA) reduces low density lipoprotein (LDL)-cholesterol concentrations in blood plasma (Mensik and Katan, 1989). There is also increasing evidence that MUFA decrease LDL-cholesterol level without adversely affecting high density lipoprotein (HDL)-cholesterol and reduces the susceptibility of LDL to oxidation, while some PUFA decrease both LDL- and HDL-cholesterol levels (Mattson and Grundy, 1985; Roche, 2001).

The manipulation of dietary fat with the purpose of altering the fatty acid composition of the chicken meat to tailor current health recommendations for humans has promoted the substitution of animal fat sources by some UFA-rich vegetable oils. An alternative and cheaper mean of achieving this aim could be to include whole oilseeds in the diets. Sunflower seed, one of the most widely cultivated oilseeds, contains about of 500 g/kg very high UFA oil. Regarding the fatty acid composition, two main groups of sunflower varieties are commercially available: conventional (CSS), rich in linoleic acid, C18:2n-6 (580 g/kg total fatty acids TFA) (Ortiz et al., 1998) and high-oleic acid sunflower seed (HOASS), obtained recently, rich in oleic acid, C18:1n-9 (810 g/kg TFA) (Rodríguez et al., 2005).

However, broiler diets containing a relatively high concentration of C18:2n-6 have been negatively associated with soft fat tissues and high susceptibility of meat to oxidation (Zollitsh et al., 1997). The consistency and firmness of meat is related to the fat melting point, which is negatively correlated with the fatty acid unsaturation (Hrdinka et al., 1996; Sanz et al., 1999; Bavelaar and Beynen, 2003). On the other hand, diets with a relatively high content of MUFA have little effect on lipid oxidation when compared to diets with more saturated fatty acids (Lauridsen et al., 1997) and do not adversely affect to the quality of chicken meat (O'Neill et al., 1998).

Since the fatty acid composition of chicken meat can be considered an important determinant of its quality and due to the lack of data on the effect of HOASS and its refined oil (HOASO) on carcass fatty acid composition, the aim of the current study was: 1. to examine the changes in the fatty acid composition of abdominal fat and intramuscular lipids by the incorporation of a rich MUFA source to broiler diets (HOASS and HOASO) instead of a PUFA (CSS and CSO) or a more saturated source (lard), and 2. to establish the relationship between the melting point and the fatty acid pattern of abdominal fat.

MATERIAL AND METHODS

Sunflower samples

High-oleic acid sunflower seed (cv. Saxo) and conventional sunflower seed, commercially used for their oil extraction, were obtained from a commercial supplier (Koipesol Semillas SA, 41410 Carmona, Sevilla, Spain). The batches of sunflower seed were cleaned by hand to eliminate any foreign material, ground to pass through a 3.0 mm screen and stored at -20°C until used. High-oleic acid and conventional sunflower refined oils (HOASO and CSO, respectively) and lard were provided by local suppliers. Fatty acid composition of the five fat sources is shown in Table 1.

Table 1. Fatty acid composition of the dietary fat sources[1], g/kg total fatty acids

	HOASS[2]	HOASO[3]	CSS[4]	CSO[3]	Lard[3]
C14:0	ND[9]	ND	1	ND	11
C16:0	44	43	59	65	224
C16:1 n-7	ND	ND	1	ND	18
C18:0	51	43	64	36	125
C18:1 n-9	807	730	284	330	438
C18:2 n-6	72	163	581	556	145
C18:3 n-3	ND	ND	1	ND	7
C20:0	5	4	6	2	2
C20:1 n-9	ND	3	3	ND	11
C20:4 n-6	ND	ND	ND	ND	2
MUFA[5]	810	732	288	330	467
PUFA[6]	76	167	582	561	163
SFA[7]	114	101	130	109	370
UFA[8]/SFA	7.80	8.90	6.70	8.20	1.70

[1] fat source: HOASS = high-oleic acid sunflower seed, HOASO = high-oleic acid sunflower oil, CSS = conventional sunflower seed; CSO = conventional sunflower oil, and lard; [2] Rodríguez et al. (2005); [3] analysed in our laboratory; [4] Ortiz et al. (1998); [5] MUFA = monounsaturated fatty acids; [6] PUFA = polyunsaturated fatty acids; [7] SFA = saturated fatty acids; [8] UFA= unsaturated fatty acids; [9] ND = not detected

Animals, diets and samples preparation

Two hundred one-day-old female Cobb chickens, obtained from a commercial hatchery, were randomly housed in electrically heated starter battery brooders in an environmentally controlled room. The chickens were fed on a nutritionally adequate maize-soyabean meal diet for chickens of 3 wk of age. At the end of third week, after having been deprived of feed overnight, 175 chickens were

Table 2. Composition of experimental diets, g /kg as fed

Item	Diet[1]				
	HOASS	HOASO	CSS	CSO	Lard
Ingredients					
maize	561.0	532.3	573.6	532.3	532.8
soyabean meal	159.6	349.1	139.7	349.1	348.6
high oleic sunflower seed	180.0	-	-	-	-
high oleic sunflower oil	-	80.0	-	-	-
conventional sunflower seed	-	-	167.0	-	-
conventional sunflower oil	-	-	-	80.0	-
lard	-	-	-	-	80.0
soyabean protein isolate	60.9	-	81.3	-	-
calcium carbonate	9.0	9.0	9.0	9.0	9.0
dicalcium phosphate	19.0	19.0	19.0	19.0	19.0
sodium chloride	3.0	3.0	3.0	3.0	3.0
DL-methionine	1.0	1.1	0.9	1.1	1.1
butylhidroxytoluol	1.5	1.5	1.5	1.5	1.5
vitamin-mineral premix[2]	5.0	5.0	5.0	5.0	5.0
Analysed nutrient composition					
crude protein	197.0	192.0	197.1	208.5	205.8
crude fat	106.4	105.5	111.3	106.1	109.8
fatty acids, g /kg total fatty acids					
C16:0	70	76	92	85	195
C16:1 n-7	0	0	0	0	10
C18:0	38	32	25	33	86
C18:1 n-9	602	569	257	298	382
C18:2 n-6	254	289	607	562	283
C18:3 n-3	7	9	8	9	15
MUFA[3]	602	569	257	298	392
PUFA[3]	261	298	615	571	298
SFA[3]	122	120	126	128	295
UFA[3]/SFA	7.20	7.33	6.94	6.81	2.39
AMEn, kcal /kg	3200	3247	3200	3263	3256

[1] fat source: HOASS = high-oleic acid sunflower seed; HOASO = high-oleic acid sunflower oil, CSS = conventional sunflower seed, CSO = conventional sunflower oil, and lard; [2] vitamin and mineral mixture supplying (mg /kg diet): 3 retinol, 55 cholecalciferol, 25 *dl*-α-tocopheryl acetate, 2.5 menadione, 3 thiamine, 6 riboflavin, 7 pyridoxine, 0.2 folic acid, 0.02 cyanocobalamin, 0.2 biotin, 25 calcium pantothenate, 50 niacin, 1300 choline chloride, 29.5 $CuSO_4 \cdot 5H_2O$, 375.0 $FeSO_4 \cdot 7H_2O$, 138.0 $ZnSO_4 \cdot H_2O$, 277.0 $MnSO_4 \cdot H_2O$, 0.35 Na_2SeO_3, 0.20 KI, 2.1 $CoCl_2 \cdot 6H_2O$, 0.50 $Na_2MoO_4 \cdot 2H_2O$; [3]as in Table 1

weighed, moved to grower-finisher batteries, and allocated into 35 pens; each pen contained 5 chickens and was assigned to one of the 7 replicates for each of the 5 dietary treatments during 21 d prior to slaughtering. Feed and water were provided *ad libitum*. The chickens were subjected to artificial fluorescent illumination for 23 h/day and handled according to the principles for the care of

animals in experimentation established by Royal Decree 223/88 of Spain (1988). Experimental procedure was approved by the Animal Care and Use Committee of Complutense University (Madrid, Spain).

The chemical composition and the lipid profile of the experimental diets are shown in Table 2. Five isonitrogenous and isocaloric diets were formulated, included 80 g/kg added fat corresponding to 180 g/kg HOASS, 80 g/kg HOASO, 167 g/kg CSS, 80 g/kg CSO and 80 g/kg lard. Crude protein of diets was determined following the standard procedure of AOAC (1995). Metabolizable energy value (AMEn) of HOASS (Rodríguez et al., 2005) and CSS (Rodríguez et al., 1998) used to formulate the experimental diets were determined in our laboratory in preliminary experiments.

At 42 d of age, the chickens were weighed, wing-banded and fasted for 18 h before slaughtering. Broilers were stunned, slaughtered, bled and eviscerated in a commercial slaughterhouse. Carcasses were chilled, and abdominal fat, breast and thigh were removed by hand. For fatty acid analysis, 7 tissue samples per treatment, one per pen, were taken from breast excluding skin, thighs with skin and abdominal fat, freezed and stored at -20°C until required. Abdominal fat samples for melting point determination (10 per treatment) were melted, filtered and placed into thin capillary glass tubes.

Fatty acid profile and melting point determinations

Crude fat of diets was determined by extraction in petroleum ether following acidification with 4N HCl (Wiseman et al., 1992). Total lipids from tissues were extracted following the procedure described by Folch et al. (1957). Fatty acid composition was determined by gas chromatography by comparison of their retention times with their corresponding standard (Sigma-Aldrich Química, SA, Alcobendas, Madrid, Spain). The lipid extracts were esterified with a mixture of boron trifluoride (in 10% methanol), hexane and methanol (35:20:45, v/v/v) (Morrison and Smith, 1964). The resultant fatty acid methyl esters were analysed using a Chrompack CP 9001 Gas Chromatograph (Chrompack Instrumental BV, Middelbôurg, The Netherlands) equipped with a WCOT fused silica capillary column (length, 30 m; id, 0.32 mm; film thickness, 0.5 μm), and a flame ionisation detector. Analyses were performed with a temperature programme from 170 to 250°C at a rate of 3.5°C/min. Both injector and detector were maintained at 250°C. The carrier gas was nitrogen at a flow rate of 4.5 mL/min. MUFA, PUFA and SFA contents as well as UFA/SFA ratio were calculated.

The determination of melting point of the abdominal fat was carried out to estimate fat firmness. The melting point was measured by the AOAC method (1995). The capillary glass tube with the fat sample was placed into a water bath in front of a dark background and well lighted. The initial temperature of water bath was 5°C and the heating rate approximately 0.5°C/min. The melting point was defined

as the temperature at which the sample fat becomes transparent (magnifying glass was used to detect complete melting). Average of three determinations per sample was used for statistical analysis.

Statistical analysis

Data of the different variables (performance parameters, fatty acid profile within each studied tissue and melting point of abdominal fat) were analysed statistically using one-way ANOVA and means with a significant F ratio were separated by the multiple range test of Duncan ($P<0.05$). Regression analysis was also applied to relate the fatty acid content of tissues (y) to fatty acid content of diets (x), as well as melting point of abdominal fat (y) to fatty acid content of abdominal fat (x). The statistical analyses were performed by using the Statgraphics software package (version 5.0, Statistical Graphics Corporation, Rockville, MD, USA).

RESULTS

The dietary fatty acid composition of the experimental diets (Table 2) reflected the fatty acid profile of the fat source. The predominant SFA was palmitic acid (C16:0) in the lard diet (195 g/kg total fatty acids), the predominant MUFA was oleic acid (C18:1n-9) in the HOASS and HOASO diets (602 and 569 g/kg, respectively) and the linoleic acid (C18:2n-6) was the main fatty acid in the CSS and CSO diets (607 and 562 g/kg, respectively).

The values corresponding to the productive parameters are shown in Table 3.

Table 3. Effect of dietary fat source on performance parameters of chickens (21 to 42 d)

	Diets[1]					SEM
	HOASS	HOASO	CSS	CSO	Lard	
Final body weight, g	1761	1837	1767	1840	1826	41.5
Weight gain, g day^{-1}	64.7^{b}	68.2^{a}	65.0^{b}	68.6^{a}	67.6^{ab}	0.99
Feed intake, g day^{-1}	107.3	105.4	107.0	105.2	103.4	1.31
Feed-to-gain ratio, g g^{-1}	1.66^{a}	1.55^{b}	1.65^{a}	1.53^{b}	1.53^{b}	0.020

^{a,b} means in a row with no common superscripts are significantly different at $P\leq0.05$

[1] fat source: HOASS = high-oleic acid sunflower seed; HOASO = high-oleic acid sunflower oil; CSS = conventional sunflower seed; CSO = conventional sunflower oil, and lard

The inclusion of 180 g/kg HOASS and 167 g/kg CSS in diets negatively affected the body weight gain of birds compared with their corresponding oil diets. The feed to gain ratio of birds consuming the diets containing seeds was significantly ($P<0.05$) higher than that of birds fed the diets containing oil or lard.

Table 4. Effect of dietary fat source[1] on fatty acid composition of different chicken tissues

Item	Total fat g/kg fresh tissue	Fatty acid, g /kg total fatty acids									UFA[2]/SFA
		C16:0	C16:1 n-7	C18:0	C18:1 n-9	C18:2 n-6	C18:3 n-3	MUFA[2]	PUFA[2]	SFA[2]	
Abdominal fat											
HOASS		125^{c}	14.3^{b}	24.3^{c}	694^{a}	129^{b}	3.1^{ab}	715^{a}	136^{b}	149^{d}	5.7^{a}
HOASO		120^{c}	9.7^{b}	22.3^{c}	664^{b}	168^{b}	3.7^{a}	679^{b}	175^{b}	146^{d}	6.0^{a}
CSS		156^{b}	10.0^{b}	36.7^{b}	396^{d}	361^{a}	2.0^{b}	427^{d}	377^{a}	196^{b}	4.2^{b}
CSO		133^{c}	9.7^{b}	35.3^{b}	422^{d}	366^{a}	2.7^{ab}	436^{d}	371^{a}	172^{c}	4.5^{b}
lard		224^{a}	20.7^{a}	51.0^{a}	533^{c}	132^{b}	3.9^{a}	563^{c}	142^{b}	295^{a}	2.4^{c}
pooled SEM		5.31	1.54	2.70	9.17	13.84	0.53	9.36	14.21	6.95	0.25
Breast											
HOASS	19.4	123^{c}	8.1^{b}	45.7^{b}	564^{a}	188^{c}	3.0^{c}	580^{a}	248^{d}	172^{d}	4.8^{a}
HOASO	16.2	128^{c}	6.4^{b}	48.6^{b}	521^{b}	208^{c}	3.6^{b}	538^{b}	283^{c}	179^{cd}	4.6^{ab}
CSS	19.3	139^{b}	6.3^{b}	47.6^{b}	317^{d}	418^{a}	3.6^{b}	333^{d}	478^{a}	189^{bc}	4.3^{bc}
CSO	16.0	140^{b}	5.6^{b}	55.0^{ab}	329^{d}	374^{b}	3.9^{b}	346^{d}	456^{b}	198^{b}	4.1^{c}
lard	19.9	190^{a}	15.4^{a}	62.7^{a}	441^{c}	195^{c}	6.6^{a}	467^{c}	273^{c}	261^{a}	2.8^{d}
pooled SEM	1.24	3.08	1.01	3.87	8.51	6.60	0.17	8.86	6.89	5.57	0.15
Thigh											
HOASS	88.4	120^{c}	13.6^{bc}	38.1	601^{a}	189^{d}	4.0^{c}	621^{a}	217^{d}	162^{c}	5.3^{a}
HOASO	88.2	121^{c}	14.6^{bc}	38.4	572^{b}	214^{c}	5.3^{b}	593^{b}	245^{c}	162^{c}	5.3^{a}
CSS	82.3	139^{b}	10.3^{c}	48.3	332^{e}	415^{a}	4.0^{c}	352^{e}	458^{a}	190^{b}	4.3^{b}
CSO	84.6	136^{b}	18.6^{b}	51.6	373^{d}	371^{b}	5.3^{b}	400^{d}	411^{b}	189^{b}	4.4^{b}
lard	85.1	188^{a}	26.9^{a}	51.3	480^{c}	198^{cd}	7.7^{a}	515^{c}	240^{cd}	245^{a}	3.1^{c}
pooled SEM	1.83	4.17	2.49	4.92	8.91	7.88	0.26	7.80	8.23	7.53	0.24

^{a,b,c,d,e} within each tissue, means in a column with no common superscripts are significantly different at P≤0.05; [1] fat source: HOASS = high-oleic acid sunflower seed; HOASO = high-oleic acid sunflower oil; CSS = conventional sunflower seed; CSO = conventional sunflower oil, and lard; [2] as in Table 1

The effect of different dietary fat sources on the fatty acid composition of abdominal fat, breast and thigh is shown in Table 4, where it can be seen that there were significant ($P<0.05$) differences in the fatty acid content among dietary treatments in all tissues, with the exception of C18:0 in thigh. The contents of the major fatty acids (C16:0, C18:1n-9 and C18:2n-6) in each tissue reflected the fatty acid profile of the dietary fat: C18:1n-9 was the predominant fatty acid in all tissues for HOASS, HOASO and lard diets, and C18:2n-6 was the main fatty acid in breast and thigh tissues for CSS and CSO diets. In general, no differences were found in C16:0 and C18:0 (stearic acid) content in tissues when both varieties of sunflower seeds and their respective refined oils were compared (Table 4). A small increase in C18:1n-9 content (percentage of increase 4% in abdominal fat, 8% in breast and 5% in thigh) and, consequently, a reduction in C18:2n6 (13% in thigh) and C18:3n-3 (linolenic acid) content (20 and 23% in breast and thigh, respectively) have been observed with HOASS diet compared with HOASO diet. When CSS diet was compared with CSO diet, an increase in C18:2n-6 content (percentage of increase 11% in breast and thigh) together with a reduction in C18:1n-9 and C18:3n-3 contents in thigh (12 and 33%, respectively) were observed. UFA/SFA ratio did not significantly ($P<0.05$) vary in birds fed the diets containing seeds in comparison with those consuming the diets containing the corresponding refined oil.

As can be seen in Table 4, a differential response of abdominal and intramuscular fat to dietary fat source was found. In general, the differences among dietary treatments represented as relative differences in the contents of C16:0, C18:2n-6, PUFA, SFA and in the UFA/SFA ratio were more pronounced for abdominal fat than for breast and thigh. The greatest difference was found for C18:2n-6 in abdominal fat (180% in CSS with respect to HOASS). Although lower than on abdominal fat, the results of the present study also showed a high effect of treatments on breast and thigh fat. The relationship between dietary and tissue fatty acid content in the different tissues was analysed by regression analysis (Table 5). Results obtained showed a close relationship for C16:0, C18:1n-9 and C18:2n-6 in the tissues studied (r^2 ranging from 0.97 for C18:2n-6 in breast to 0.83 for C16:0 in thigh) and consequently, the coefficients of determination for MUFA and PUFA were also very high (from 0.97 to 0.89).

The different fatty acid profile caused by the dietary fat sources resulted in significant ($P<0.05$) differences in the melting point of abdominal fat. The chickens fed the lard diet had the highest value (36.0°C), whereas those fed the HOASS diet or its oil had the lowest values (21.9 and 21.3°C, respectively). The birds fed the CSS diet and its oil showed intermediate values (24.4 and 25.9°C, respectively). Differences between the diets containing the seeds and the diets containing their respective refined oils were not significant ($P>0.05$). To further

asses this relationship, linear regressions relating melting point (y) to fatty acid composition (x) of abdominal fat were done. The results showed that the highest correlation was obtained for SFA content as independent variable (r=0.89; y=9.60+0.085x); UFA/SFA ratio also gave a good estimation of the melting point (r=-0.83; y =40.29-3.158x).

Table 5. Linear regression analysis relating tissue fatty acids (y) to dietary fatty acids (x)

Item	r^2	A	SE	P value	B	SE	P value
Abdominal fat							
C16:0	0.86	67.834	6.4672	***	0.8086	0.05699	***
C16:1 n-7	0.47	10.929	0.8094	***	0.9786	0.18098	***
C18:0	0.39	18.933	3.6202	***	0.3500	0.07523	***
C18:1 n-9	0.96	178.987	14.3551	***	0.8611	0.03231	***
C18:2 n-6	0.89	-50.968	18.1268	**	0.7073	0.04243	***
C18:3 n-3	0.07	1.714	0.8738	ns	0.1429	0.08738	ns
MUFA[1]	0.95	205.85	15.4171	***	0.8453	0.03456	***
PUFA[1]	0.89	-53.613	18.6247	**	0.7194	0.04273	***
SFA[1]	0.83	70.940	10.3572	***	0.7623	0.06008	***
UFA[1]/SFA	0.64	0.849	0.5110	ns	0.6050	0.07964	***
Breast							
C16:0	0.89	90.509	3.4652	***	0.5158	0.03054	***
C16:1 n-7	0.65	6.607	0.5079	***	0.8821	0.11358	***
C18:0	0.21	41.660	3.8307	***	0.2396	0.07961	**
C18:1 n-9	0.92	141.615	15.5973	***	0.6946	0.03511	***
C18:2 n-6	0.97	19.428	8.4017	*	0.6447	0.01967	***
C18:3 n-3	0.89	-0.175	0.2733	ns	0.4469	0.02733	***
MUFA	0.92	157.555	16.4025	***	0.6971	0.03677	***
PUFA	0.97	82.294	8.7018	***	0.6491	0.01996	***
SFA	0.79	128.509	6.8656	***	0.4519	0.03983	***
UFA/SFA	0.72	1.957	0.2486	***	0.3551	0.03874	***
Thigh							
C16:0	0.83	86.235	4.6852	***	0.5267	0.04129	***
C16:1 n-7	0.37	14.250	1.2927	***	1.2607	0.28906	***
C18:0	0.03	41.074	5.0568	***	0.1044	0.10508	ns
C18:1 n-9	0.93	158.173	16.1666	***	0.7434	0.03639	***
C18:2 n-6	0.96	27.557	9.9081	**	0.6267	0.02319	***
C18:3 n-3	0.80	0.574	0.4210	ns	0.4789	0.04210	***
MUFA	0.93	184.184	16.2097	***	0.7360	0.03634	***
PUFA	0.96	46.799	10.5038	***	0.6552	0.02410	***
SFA	0.63	124.067	9.4897	***	0.4139	0.05505	***
UFA/SFA	0.53	2.108	0.4049	***	0.3839	0.06311	***

[1] as in Table 1

SE = standard error

* P<0.05, **P<0.01, *** P<0.001, ns = non significant

DISCUSSION

The lower chicken performance observed for sunflower seed containing diets (HOASS and CSS) compared with those containing either refined oils (HOASO and CSO) or animal fat (lard) may be explained by the higher crude fibre content of the former diets. In fact, it has been reported than high fibre content may decrease the bulk density of diet and cause alterations in the jejunal mucosa (Arija et al., 2000). Likely, a decrease in the apparent digestibility of amino acids has been described by Rodríguez et al. (2005) when the concentration of fibre increased in the diet. Results of the present work are in accordance to those found by Arija et al. (1998) for CSS containing diets and those published by Rodríguez et al. (2005) in birds fed diets containing 100 and 200 g/kg HOASS.

Changes in the composition of the abdominal and muscle fat caused by the variable composition of dietary fat confirm earlier findings (Leskanich et al., 1997a; O'Neill et al., 1998; López-Ferrer et al., 2001). The small differences found on fatty acid profile of tissues when sunflower seed diets (HOASS and CSS) and their corresponding oil diets (HOASO and CSO) were compared, could be explained, at least in part, by the different concentration of individual fatty acids in seed diets with respect to oil diets.

By feeding chickens with a source of fat high in C18:1n-9 (HOASS or its oil) or C18:2n-6 (CSS or its oil) the proportion of MUFA and PUFA, respectively, increased in abdominal fat as well as in breast and thigh muscles. In the tissues studied, the proportion of MUFA surpassed 530 g/kg of the total fatty acids (TFA) for chickens fed on HOAS (seed and oil) diets, and the concentration of PUFA exceeded 370 g/kg of TFA for chickens fed on CS (seed and oil) diets. In breast and thigh muscles, this resulted in a two fold increase in MUFA/SFA ratio for HOASS and a two and a half increase in PUFA/SFA ratio for CSS in contrast to birds fed the lard diet. Similar increases in the MUFA content of fat tissue have been reported for chickens fed olive oil containing diets (O'Neill et al., 1998). Dietary HOAS (seed and oil) increased significantly the UFA/SFA ratio in all tissues in comparison to CS (seed and oil) diets (percentage of increase ranging from 36 to 10%) and lard diet (percentage of increase from 150 to 64%). The current study clearly revealed that muscle fatty acid can be manipulated to increase MUFA/SFA or PUFA/SFA ratios. In addition, future studies should concentrate on enrichment of poultry meat with n-3 PUFA since recommendations on human nutrition have stressed the importance of decreasing n-6/n-3 PUFA ratio (Leskanich, 1997b).

Results of the current work showed a more efficient modification of adipose than intramuscular fat profile, which was probably due to the physiological lipid storage function of adipose tissue. Several authors have reported this differential response, however, while Hrdinka et al. (1996) found a marked effect on abdominal

fat and a limited effect on intramuscular lipids, Sanz et al. (2002) reported that the effect on intramuscular lipids depends on lipid class: triacylglycerols were highly affected whereas polar lipids were little affected by the diet. In broilers, lipid classes are unevenly distributed in different tissues. Ratnayake et al. (1989) reported that triacylglycerols accounted for 43, 83 and 100% of total lipids in breast, thigh and skin of chickens fed a standard diet. Although lower than on abdominal fat, dietary effect on intramuscular fat was also high in the present study and, consequently, high correlation between dietary and abdominal fat as well as between dietary and intramuscular lipids was obtained for C16:0, C18:1n-9 and C18:2n6. The slopes of the regression lines ranged from 0.69 to 0.86 for C18:1n-9 and from 0.63 to 0.71 for C18:2n-6, indicating an efficient incorporation of both fatty acids in tissues. These findings confirm the results reported by Scaife et al. (1994) for female broilers fed on diets containing 50 g/kg of supplemental oil, that found a strong correlation between dietary and breast fatty acid contents. In contrast to this, the limited effect on muscle tissues found by Hrdinka et al. (1996) could be explained by the lower level of fat added (35 g/kg). As it has been stated, the dietary fatty acids incorporated into the muscular tissues will be relatively more diluted by *de novo* synthesized fatty acids at low fat intakes than at high fat intakes.

The inclusion of sunflower (seeds and oils) in chicken diets has resulted in significant decreases of melting point of abdominal fat with respect to lard diet. Of the regression analyses performed, linear equation relating melting point and SFA content of abdominal fat showed the highest coefficient of determination (r^2=0.80). Melting point is an indicator of the consistency of chicken fat (Bavelaar and Beynen, 2003), and it is associated to the fatty acid composition. Because decreasing the firmness of the fat tissue can be disadvantageous in the marketing of broiler meat (Valencia et al., 1993), it is important to consider this aspect of meat quality when shifting the fatty acid profile in chicken tissues. Recently, Bavelaar and Beynen (2003) demonstrated that fatty acid composition and melting point of the adipose tissue are strongly determined by the qualitative fatty acid intake, and the regression equations obtained can be used to formulate diets to modify broiler meat regarding to the health consumer and meat quality.

CONCLUSIONS

It is concluded that the seeds of high-oleic acid and conventional varieties of sunflower might be used in poultry feeding in order to increase, respectively, MUFA and PUFA contents in both abdominal adipose tissue and intramuscular fat. The feeding of both types of seeds had similar effects to their respective refined

oils on the unsaturated to saturated fatty acid ratio of the chicken tissues and melting point of abdominal fat. Nevertheless, they showed a negative influence on fat firmness when compared with the dietary inclusion of lard.

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